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PHYSIOLOGICAL AND BIOCHEMICAL PARAMETERS AMONG A POPULATION OF BAKERS EXPOSED TO ENVIRONMENTAL HEAT

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Abstract
Objectives: The aim of this study was to determine the physiological and biochemical changes among bakers, induced by heat exposure at the workplace. **Material and Methods:** Information was collected by means of a self-administered questionnaire. Vital signs were measured and recorded by a trained nurse before and after each work shift. A venous blood sample was drawn at the end of each work shift. The mean wet-bulb globe temperature (WBGT) index in the bakeries and offices was measured. **Results:** This was a cross-sectional study involving 137 bakers working in 20 bakeries, and 107 control subjects comparable in terms of age, race, marital status, years of service, income, and cigarette smoking. There was a significant weight loss and increase in the respiratory rate, the heart rate, and oral body temperature among the bakers compared to the control group. Sodium levels were significantly lower, while blood urea nitrogen levels were significantly higher, among the bakers than in the control group. There were unfavorably hot working conditions in the bakeries: the WBGT index in the bakeries was 37.4°C while the average WBGT for the offices was 25.5°C. **Conclusions:** The changes in the physiological and biochemical parameters among the bakers were found to be associated with exposure to high environmental heat in the bakeries, as judged by the WBGT index. Preventive measures should be aimed at reducing the adverse effects of heat exposure among bakers and should be directed towards the man-machine-environment triad. Int J Occup Med Environ Health. 2022;35(3):265–72

Key words:
physiological, parameters, heart rate, biochemical, bakers, heat

INTRODUCTION

Exposure to high environmental temperatures has determinant effects on the health of exposed individuals, particularly employees working in occupations involving heat exposure. This finding has some serious implications for developing countries where skilled labor is scarce and its replacement is often difficult [1,2].

Heat exposure has been shown to result in a range of illnesses (heat stroke, heat exhaustion, heat syncope, heat cramps, behavioral disorders, etc.) as well as injuries and reduced productivity in the workplace [2–8].

Bakery workers are regularly exposed to strenuous manual activities including heavy lifting, forceful exertion, repetitive tasks, and awkward postures leading to upper limb musculoskeletal disorders. These disorders are common among bakers as they handle dough, stand for prolonged periods next to a hot oven, bend repeatedly to insert heavy trays into the hot oven, lift heavy items, work for long hours, and do shift work. These findings have been reported in several different studies [9–12].

Many workers exposed to high environmental temperatures are at risk of developing heat strain leading to physi-

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ological changes. These physiological parameters suggest that bakery workers are exposed to a higher physical workload and a risk of heat stress. Several studies have evaluated increased heart rates, respiratory rates, core body temperature, and blood pressure as physiological indexes associated with heat stress [13,14].

The central nervous system in humans is responsible for thermoregulation, which keeps the body temperature in equilibrium. The anterior hypothalamus receives signals from receptors located in the skin, muscles, and other parts of the body. It then releases neurotransmitters to alter the physiological mechanisms of the body to get rid of the excessive heat by varying the rate and amount of blood coming from the heart and circulating to the skin. A body subjected to heat undergoes changes in skin temperature, body temperature, heart rate, and sweat rate. Body weight has also been reported to decrease in groups exposed to heat because of sweating, which has been found to be dose dependent. These changes have been attributed to dehydration because of the difficulty of maintaining skin blood flow against an increase in heat gain [15,16].

The sodium concentration in the blood and other tissues can be readily altered by exposure to heat. Sodium is a component of sweat and, along with other electrolytes such as potassium and chloride, is regulated by physiological mechanisms of the human body.

Plasma volume depletion has been implicated as the reason for increased blood urea nitrogen (BUN) and decreased potassium levels; this can be explained by excessive sweating. Biochemical tests have shown a significant increase in mean serum sodium, potassium, and chloride, and a significant decrease in serum creatinine and total protein, among individuals after heat exposure [15,17–19].

There are several heat stress indexes used for the assessment of exposure to high environmental temperature [20,21]. The wet-bulb globe temperature (WBGT) index has been validated and used globally as an acceptable index to evaluate the levels of environmental heat [22,23].

Although there is a significant body of research on heat exposure in the workplace, there is insufficient information regarding the prevalence of heat disorders among bakers in terms of the particular physiological and biochemical responses they experience because of exposure to high environmental temperatures.

This study aimed to determine the physiological and biochemical changes among bakers, induced by heat exposure in the workplace, and to contrast these with a control (unexposed) group.

MATERIAL AND METHODS

This was a cross-sectional study where all 137 bakery workers from 20 bakeries in the city of Al-Khobar, Saudi Arabia, participated in the study, giving a response rate of 100%.

The control group (N = 107) was selected from individuals who were characterized by the following:

– no exposure to heat in their present jobs (salesmen at offices, butchers, janitors at shops, and others);
– no past history of work demanding exposure to high environmental temperatures;
– a pattern of working long hours, including night and early morning shifts, to be comparable to the bakers in terms of work hours and work shifts.

Furthermore, the majority of these control group subjects were selected because they performed physical work (the authors assumed that the control group had a similar energy expenditure as the bakers).

All participants (bakers and control) were invited to complete a standard questionnaire about demographic data, personal information, work history, medical history, and fluids consumed during the work shift.

Vital signs (weight, respiratory rate, blood pressure, and oral body temperature) were recorded by a trained nurse before and after each work shift. The weight of each participant (in kilograms) was recorded using the Fazzini SRL weighing scale (Vimodrone, Italy).

The diagnosis of obesity in the study sample was obtained by the body mass index (BMI). Normal weight corresponds to a BMI of 18.5–24.9, overweight to a BMI of 25–29.9, while obese people have a BMI of ≥30.0.
The respiratory rate was measured by counting the chest movements during respiration for 1 min. The heart rate was recorded by digital palpation of the radial pulse at the wrist for 2 separate min and the average was then taken. Blood pressure was measured by a mercury sphygmomanometer while the subject was sitting.
Oral body temperature was recorded sublingually for 2 min using a mercury-in-glass thermometer calibrated in degrees centigrade. The core body temperature as reflected by rectal temperature is more accurate than oral temperature; however, the authors took precautions (no eating or drinking hot or cold foods or fluids and no smoking for 30 min preceding the measurement of oral body temperature) to obtain a high degree of accuracy; hence the oral temperature measured in this study can be considered as surrogate for the core body temperature.
Venous blood sampling from the antecubital fossa was drawn from all subjects at the end of each work shift. All blood samples were sent immediately to a central laboratory, where they were processed within 1 h using an Astra-8 American automated machine to analyze the serum for sodium, potassium, chloride, BUN, and creatinine concentrations.
It had originally been planned to draw blood samples from all workers, both before and after the work shift, but this proved unacceptable to the workers during the pilot study.
Measurements of the WBGT index in degrees centigrade were performed according to ISO 7243 standards. These measurements were taken simultaneously in different locations where workers performed routine job duties at each bakery and office, using a WBGT meter, 8778 AZ-AZ instrument. The study was conducted during the summer season when the average local outside air temperature was 33°C. Data were checked and fed into a personal computer daily, and a SPSS v. 20 was utilized in the analysis.
The t-test was also used to compare the average age, duration of work, income, and biochemical parameters among the bakers and the control group. Paired t-tests were used to compare pre- and post-shift physiological changes. The χ^2 test and Fisher's exact test were used to compare differences in the percentages of categorical variables. P-values of <0.05 were taken as statistically significant.

Ethical consideration

The Imam Abdulrahman bin Faisal University's ethical review board (IRB-2018-03-194) approved the study. Then, the management of the bakeries was officially contacted, and their cooperation was requested. Written consent from all participants was obtained after an explanation of the aim of the study. The participants were told that they were free to withdraw from the study at any time, and confidentiality of recorded data was assured.

RESULTS

The bakers (137) were compared to the non-exposed (control) group (N = 107) in terms of age, gender, marital status, ethnic origin, education, duration of work, smoking habits, and income.
The mean age of the bakers was 32.3 years with a standard deviation (SD) of 7 years, and the mean age in the control group was 30.5 years with a standard deviation of 7.5 years (Student's t-test, p = 0.054). All the bakers and non-exposed group members were males. As for the marital status, 81.0% of the bakers and 72.9% of the control group were married while the rest were single. The difference proved to be statistically insignificant (p = 0.132).
As for ethnic origin, 51.0% of the bakers and 37.4% of the non-exposed individuals were Indian, while the rest were of other ethnic origins. The difference proved to be statistically insignificant (Fisher's exact test, p = 0.221).
Of the exposed group (the bakers), 22.2% were illiterate and 30.7% had primary school education; approx. 19.7% of the bakers had secondary school education or higher,

Table 1. Physiological parameters before and at the end of the work shift in the bakers working in 20 bakeries and the control group, Al-Khobar, Saudi Arabia

Parameter	Participants (N = 244)								p
	bakers (N = 137)				control group (N = 107)				
	before the work shift (M)	at the end of the work shift (M)	change	SD	before the work shift (M)	at the end of the work shift (M)	change	SD	
BMI for overweight and obese individuals [%]	29.75	29.40	–0.35	0.36	30.11	30.18	0.07	0.38	<0.0001
Respiratory rate [breath/min]	16.30	18.62	2.32	3.62	17.02	17.35	0.33	3.14	<0.0001
Heart rate [bpm]	72.30	75.92	3.62	9.69	74.45	72.18	–2.27	8.72	<0.0001
Blood pressure [mm Hg]									
systolic	113.22	112.11	–1.11	11.60	114.23	111.89	–2.34	8.65	0.345
diastolic	75.41	75.04	–0.37	8.02	73.32	73.36	0.04	7.61	0.689
Oral body temperature [°C]	37.33	37.57	0.24	0.36	37.21	37.24	0.03	0.34	<0.0001

BMI – body mass index.

while 22.4% of the non-exposed individuals had secondary school education or higher (Fisher's exact test, p = 0.644).

The mean duration of the present work of the bakers was 4.7 (SD = 2.5) years compared to 4.0 (SD = 2.8) years for the control group. The difference was statistically insignificant (Student's t-test, p = 0.534).

As for the smoking status, 63.5% of the bakers were current smokers (still smoking during the time of this study) compared to 52.3% in the control group, while the percentages of ex-smokers (who had stopped smoking ≥1 month prior to the study) among the bakers and the non-exposed individuals were 9.5% and 14.0%, respectively. The remaining subjects had never smoked. The differences were statistically insignificant (χ^2, p = 0.198). The mean numbers of cigarettes smoked per day among the bakers were 9.9 (SD = 10.9) compared to 10.8 (SD = 12.7) in the control group, and the difference was statistically insignificant (p = 0.544).

The average income of the exposed group was 1107 Saudi Arab Riyals (SAR) per month, compared to SAR 1341 for the control group, and the difference was statistically insignificant (p = 0.076).

It was, therefore, apparent that the 2 groups (the bakers and the non-exposed individuals) were comparable in terms of all possible confounding factors.

It is believed that the bakers involved in this study, in contrast to the control group, were acclimatized by virtue of their continuous occupational exposure to heat. Heat acclimation will not protect trained individuals from the adverse effects of exposure to environmental heat [24,25].

Table 1 shows the average physiological parameter measurements for the participants before and at the end of the work shift.

Based on Table 1, using the BMI method, the mean BMI for overweight and obese subjects was 29.75 before the work shift, while it was found to be 29.40 at the end of the work shift among the bakers, compared to 30.11 and 30.18, respectively, in the control group.

On the other hand, it can be seen in Table 1 that there was an average weight (kg) reduction by the end of the bakers' shift of approx. 350 g. The control group had an increase in the post-shift weight of 70 g. This difference was highly statistically significant ($p < 0.0001$).

The respiratory rate had increased significantly in the bakers compared to the control group by the end of the work shift (Table 1, $p < 0.0001$).

There was a significant increase in the post-shift heart rate among the bakers (3.26 bpm) while the non-exposed individuals had a decreased heart rate (–2.27 bpm) (Table 1, $p < 0.0001$).

The systolic blood pressure decreased, in average terms, for both the study group and the control group, while the diastolic blood pressure showed a decrease in the exposed subjects and an increase in the control group. However, none of these changes attained a level of statistical significance ($p = 0.345$ for the systolic and 0.689 for the diastolic blood pressure, Table 1).

The results in Table 1 showed a highly significant increase in oral body temperature among the exposed group (the bakers) compared to the control group ($p < 0.0001$).

Table 2 shows that the bakers had mean sodium levels which were slightly lower than those of the control group ($p = 0.009$). The average BUN of 5.43 mmol/l of the bakers was significantly higher than the average BUN of the control group (4.79 mmol/l) with a p-value of <0.0001. There was no statistically significant difference between the mean levels of potassium, chloride and creatinine of the exposed group and the control group.

Some of the bakers (79.4%) drank less fluids (water and juice) during work than the control group (90.5%) and the difference was statistically significant ($p = 0.014$). For the bakers, the frequency of fluid drinking was the lowest (9.4%, only 13 out of 137 bakers) after the first 30 min of work but it progressively increased, with very little fluid (37.2%, 51 out of 137 bakers) being taken after 90 min of work. The control group showed a reversed pattern (25% and 11.3%, respectively, $p < 0.001$). The bakers were exposed to heat for 10 h each day with a lunch break of 30 min, 7 days a week. They also worked for long hours, including night and early morning shifts, and under pressure to complete certain tasks within a limited time. During this period, they did not rest and did not realize the need for fluid during work.

Table 2. Biochemical parameters in the bakers working in 20 bakeries and the control group, Al-Khobar, Saudi Arabia

Parameter	Participants (N = 244)		p
	bakers (N = 137)	control group (N =107)	
Na [mmol/l] (M±SD)	141.25±2.67	141.99±2.20	0.009
K [mmol/l] (M±SD)	4.03±0.81	4.07±0.46	0.637
Cl [mmol/l] (M±SD)	105.88±3.64	105.79±2.87	0.827
BUN [mmol/l] (M±SD)	5.43±1.14	4.79±1.43	<0.0001
Cr [mmol/l] (M±SD)	86.44±12.43	85.47±13.42	0.56

BUN – blood urea nitrogen; Cl – chloride; Cr – creatinine; K – potassium; Na – sodium.

The bakers (1.23 clo) had, on average, a mean total intrinsic clothing insulation (total I_{cl}) lower than the control group (1.32 clo) and the difference was highly significant ($p < 0.0001$). This means that the bakers wore lighter clothes than the control group.

When the values of the WBGT index in the bakeries were compared with the readings in the offices (for the control group), the mean WBGT index in the bakeries was 37.4°C and that in the offices was 25.5°C ($p < 0.0001$).

DISCUSSION

In this study, the monitoring of physiological, biochemical, and environmental conditions was carried out among bakery workers in the city of Al-Khobar in Saudi Arabia.

Heat stress levels were measured using the WBGT index to evaluate the impact of environmental factors on the participants. The response of workers' bodies to heat stress is expressed as physiological parameters that can be estimated by measuring the heart rate, the respiratory rate, and core body temperature, while biochemical parameters can be estimated by changes in electrolyte concentrations in the blood as a result of dehydration in bakers exposed to high environmental temperatures.

The findings of a significant weight loss among the bakers involved in this study, by the end of the work shift, were consistent with previous studies [26–28]. The resulting decrease in weight among the bakers could be explained by the loss of water and electrolytes due to sweating during work in high environmental temperatures. The maximum sweat rate without excessive strain may reach 1 l/h to eliminate heat and to cool the body during work, depending on the state of hydration [27].

The increased respiratory rate among the bakers agreed with the findings reported in other studies and was explained by stimulation of the motor cortex and excitation of the proprioceptors during heat exposure [15,29].

The increase in the heart rate among the bakers involved in this study was also in line with other studies. Dehydration among workers exposed to high heat was a reason for this change [16,18,27,30].

The blood pressure among the bakers involved in this study decreased while there was no statistical difference when the bakers were compared to the control group, most likely due to the sample size of the control group. Blood pressure was reported to decrease among workers exposed to heat in previous studies [31,32].

The increase in oral body temperature was significantly higher among the bakers compared to the control group, which could be explained by heat exposure. The same finding was reported in workers exposed to high environmental temperatures [6,33].

The physiological parameters among the bakers are influenced by working in a hot environment. Several studies have evaluated increased heart rates, respiratory rates, core body temperature, and blood pressure as physiological indexes associated with heat exposure. The bakers involved in this study displayed biochemical changes that could be explained by exposure to heat resulting from dehydration; this was in line with the results of previous studies [17,27].

The bakers who reported low levels of fluid consumption at work were more likely to experience heat-related physiological and biochemical changes. A lower fluid intake, while working in high heat, may result in dehydration; this is consistent with other studies [17].

It is noted that the bakery environments in Saudi Arabia, as judged by the WBGT index measurement, exceed the American Conference of Governmental Industrial Hygienists threshold limit value for working in hot environments [34]. This indicates that the bakers involved in this study indeed work under high environmental temperatures, which is consistent with other studies where a significant relationship was found between the WBGT index and the physiological and biochemical parameters [27,35].

In this study, the authors found that heat exposure potentially impacts on bakers' health in Saudi bakeries. Improvements in workplace conditions and workers' training are key interventions for maintaining bakers' health.

CONCLUSIONS

The changes in the physiological (weight, respiratory rate, heart rate, and oral body temperature) and biochemical (mean sodium and BUN) parameters among the bakers who were exposed to heat in this study were found to be significantly higher than those of the non-exposed individuals. High environmental temperatures were recorded in Saudi bakeries, as judged by the WBGT index, which can explain the findings of this study. Preventive measures should be aimed at reducing the adverse effects of heat exposure among bakers and should be directed towards the man-machine-environment triad.

Limitations of this study

As with other cross-sectional studies, this study is susceptible to survivor bias because it assessed prevalent rather than incident cases and did not consider people who had retired or resigned.

It was originally planned to have a control group twice the size of the study group; unfortunately, as great difficulties were encountered, a 1-to-1 ratio was studied instead.

It is also likely that all the personal information is subject to reporting bias, as it was collected by means of a self-administered questionnaire.

Blood samples were drawn from all participants during work, rather than before and after work. Therefore, the authors were unable to investigate appropriate changes in the biochemical parameters among the bakers exposed to high environmental temperatures.

Additionally, this study was conducted among male bakers, and the authors were unable to carry out gender difference analysis amidst heat exposure. However, this does not represent a selection bias as it reflects the nature of this occupation that is only performed by males in Saudi Arabia.

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